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The Retention of Muscular Strength Among University of North Dakota Football Players

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THE RETENTION OF MUSCULAR STRENGTH AMONG UNIVERSITY OF NORTH DAKOTA FOOTBALL PLAYERS

by
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This thesis submitted by Henry A. Biesiot in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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ABSTRACT

This study was conducted to evaluate changes in muscular strength over a spring practice season. Pre-season and post-season tests were administered to seventeen University of North Dakota football players. The test items included shoulder extension, shoulder flexion, elbow extension and knee extension. Static strength was the only physical attribute measured.

A t test of significance for related groups was used to analyze the results at the 0.05 level of significance. Significant gains occurred in the elbow extension test. Significant losses occurred in the shoulder flexion test and in the knee extension test. The shoulder extension test resulted in a loss of strength.

CHAPTER I

INTRODUCTION

Athletic or motor ability of individuals is, to a large degree, determined by muscular strength and conditioning. Success in football is often determined by physical aspects of the game. For this reason, football coaches are concerned with the development and maintenance of muscular strength in their athletes. Muscular strength is also a major requirement for the prevention of injuries, which at times may plague players in the game of football. It was the purpose of this study to investigate muscular strength retention during a spring practice season.

In stressing the importance of muscular strength, Clarke (1) stated:

> Man's existence and effectiveness depend upon his muscles. Volitional movements of the body or any of its parts are impossible without action by skeletal muscles. One cannot stand, walk, run or jump without the contraction of many muscles throughout the body. The heart is a muscle; death occurs instantly when it ceases to contract. The good condition of muscles, their strength and endurance is essential to man.

For years, it was generally believed by many connected with athletics that there was an automatic increase of strength and fitness while participating in football. In the recent past, coaches have no longer taken this for granted and have strived for the development and maintenance of muscular strength in their athletic programs.

A number of investigators (2, 3, 5, 6, 7, 8, 9, 10) have stated that muscular strength is of great importance in football and other athletic events. Strength is important not only because of success probabilities, but also in the role of injury prevention.

In football, the muscles of the legs and arms are constantly being called upon to perform various movements which the game demands. It is highly desirable that these muscles be maintained at an optimum level of strength to respond to the demands that are made.

Definition of Terms

Physical Fitness.--The development and maintenance of a strong physique and soundly functioning organs.

Muscular Strength.--Contractile power of muscles in a single maximum effort.

Static Strength.--The capacity of an individual to exert maximum muscular force against an object with no obvious change in angle of the joint or length of the muscle.

Statement of the Problem

The purpose of this study was to determine if there was a retention of muscular strength during the spring football period at the University of North Dakota. Areas tested for strength retention were those frequently used in football participation. These were muscles of the shoulder girdle, forearm and those used in knee extension. The hypothesis was that there is a retention of muscular strength over the spring practice season. The null hypothesis stated that there was no significant retention of muscular strength over the spring practice season.

Related Literature

McCloy (2) stated that an important use of strength tests is that of predicting potential athletic ability. McCloy developed a theory that arm strength is accurate as a predictor of general motor ability as is total strength.

Importance of strength in football has been shown by DiGiovanna (3), who substantiated the common claim that factors of body structure, muscular strength, and explosive power were associated with athletic success. Larson (4) also stated that his strength tests could be used as an index to motor ability.

In tests made by DiGiovanna (3) results showed football backs to be moderately stronger in back, leg and arm push than the non-athlete group. The largest differences in groups came between football linemen and the non-athlete group. These differences were found in weight and arm girth. From his tests, DiGiovanna stated that explosive power is important to linemen, but apparently strength is of even greater importance.

In comparing preseason physical testing and postseason subjective rank of selected high school football players, Thompson (5) found that the strength index successfully predicted 83 per cent of those selected by their coaches as the top football players. The strength index produced a higher correlation with the subjective ranking than did tests of speed, intelligence, and coordination. Thompson concluded that strength was the most important single qualification for success in motor activities and that strength was a greater essential than speed in attaining success in football.

One of the possible consequences of many types of athletic competition is the chance of physical injury. Participants from Little League to the professional ranks constantly face the possibility of injury. For a long period of time, coaches have maintained that strength and fitness were important in the prevention of injuries. This has been affirmed by several investigators (5, 6, 10). Though strength has often been developed to prevent injury, it may be developed in order to rebuild injured areas to normal strength. Biggs (6) stated, "Proneness to injury may be influenced by insufficient muscular strength which is required to protect the body against stress."

Staton and Butler (7) stated that an investigation involving thousands of Naval Aviation Cadets during World War II disclosed incidence of injury was highest in football. Research on high school football players in Indiana showed that one in five competitors sustained some form of injury during the regular season and that one in five injuries were fractures. It was observed that most of the injuries were sprains, contusions, or fractures.

Staton and Butler reviewed a study on the 1958 British Empire games, involving 1,122 athletes, and then concluded that most sports injuries are a result of poor coordination. Coordination is an essential facet of motor fitness which may be developed in conjunction with muscle strength.

Staton and Butler also stated that muscle strength was valuable in protecting against joint damage involving ligaments or cartilage.

Weiss (8) stated:

> Experience has taught us that regular play develops enough fitness to sustain us in a friendly game. But where the objective is to win in competition, the chances are that the sport, by itself, will not develop the level of strength and endurance that competition demands.

Weiss further stated:

> Johnny Wiessmuller's World record in the 100 yard freestyle in 1927 of 51 seconds has been broken and lowered to 48.2 seconds. Part of the reason for better performances has been the development of intensive physical conditioning exercises to develop strength and endurance.

In football today, with emphasis on specialists, frequency of exercise in game situations may be relatively low. To excel, players need a level of fitness which their specific duties may not develop. Biggs (6) stated that no athlete performs at his best if his physical condition is poor--it has to be the best. There is nothing about football that is unimportant, but good conditioning is foremost. Good training or conditioning will provide more strength which will usually give better balance, agility, and endurance.

McPartlin (9) stated that strength training has been a sadly neglected feature of many training schedules. This is usually true as more time is devoted to skill and tactical training. Weiss (8) also stated coaches are learning that their teams cannot attain peak physical condition solely by practicing the sport. The practice sessions lack something that is needed to build and maintain strength and endurance. In regard to the developing of strength, McPartlin (9) stated, "Strength with efficiency must be the aim, the muscles that stretch the arms and legs must be strengthened."

Spackman (10) noted that research tells that many football players are weaker at the end of the season than they were at the start. This is due to repeated trauma to all the joints and muscles.

Marti (11) stated that football did not appear to influence size in any marked degree; however, the strength improved considerably especially while participating in football.

Spackman (12) advised that football players work on strength development at least ten minutes every day during the season to maintain and improve muscle strength.

For many football players, conditioning programs are designed for an entire year. Much of the off-season training is concerned with strength training, which is at times neglected during the regular season. Hettinger (13) stated that when compared to a once-a-day program an every other day training session produced an increase in strength of about 80 per cent that of the once-a-day program. With two training sessions per week the increase was about 60 per cent. When training sessions were held only once a week only about 40 per cent of the improvement was obtained as compared with the once-a-day program and one training stimulus every fourteen days produced no change at all in muscle strength. This showed there was no training effect when the interval between training stimuli was too long. Hettinger also stated:

> When there is a training session each day, there is a relatively rapid increase in muscle strength and likewise a rapid decline in muscle strength when training is discontinued. The loss is not nearly as rapid when muscle stimuli are given only once a week.

Most football practice sessions are conducted for a period of one to two hours of time. These practices usually start with stretching or a warm-up exercise of some variety. After this has been completed, the remainder of the practice is spent in fundamentals, execution of team work and conditioning. The amount of time spent on these phases may vary from one training program to another, as may the teaching techniques involved. Different practice programs may vary in the development and maintenance of physical fitness and muscular strength. Unless fitness and strength are measured and evaluated, the value of the practice program may not be fully assessed.

From observations made while testing high school football players, Boschee (14) stated there was an increase in physical fitness in activities testing flexibility, strength and endurance. Retention was shown up to one month after the season in all aspects of the American Association of Health, Physical Education and Recreation Youth Fitness Test, with the exception of the softball throw.

Many studies of muscular strength measurements have included a back-leg dynamometer and grip dynamometer as testing equipment. Investigations in recent years have shown a wide use of a cable tensiometer as a testing instrument of muscular strength.

Lowenberger (15) developed a strength composite of three cable-tension tests which may be used to indicate total body strength. The tests were: (1) shoulder extension, (2) knee extension, and (3) ankle plantar flexion.

Fylling (16) stated that, of six different methods of measuring strength and its relationship to endurance, the cable tensiometer was the most reliable procedure in the measuring of muscular effort.

In a study of cable tensiometer measurements, Alderman and Banfield (17) found that a random administration of test items did not result in significant differences in reliability when compared to a standard order. Neither did the use of the best scores rather than the average scores result in any changes in reliability.

Two frequently used methods of strength development in football training have been the use of isometric and isotonic exercises. Measurement of muscular strength has been recorded as static or dynamic strength.

Berger and Blaschke (18) both reported there was a significant relationship between motor ability and both static and dynamic strength. Results of tests administered by Berger and Blaschke indicated no significant differences were found between static and dynamic strength on any of the motor ability tests except for the leg power test.

Berger and Henderson (19) stated the relationships between leg power and both static and dynamic leg strength were highly significant, but not significantly different from each other. The findings indicated that neither static leg strength nor dynamic leg strength was more related to leg power than the other.

Bender and Kaplan (20) indicated that failure in the dynamic movement of a pull-up could be predicted by isometric measurements. Those who eventually became successful reached predetermined isometric strength levels necessary for success, and the unsuccessful never attained those levels.

Jackson (21) presented results of his study which indicated that individual differences in muscular strength are a function of the arms and legs. Jackson further stated that if the weight load is constant and sufficiently heavy, static and dynamic measures performed to exhaustion sample the same basic ability as tests that require a maximum force over a brief period of time.

Summary of Related Literature

Many coaches and researchers are interested and concerned with the development, maintenance and measurement of muscular strength. Many of the studies indicated a need for muscular strength. This strength plays an important role in the athletic performance of an individual. Not only is strength instrumental in an individual's motor ability, but it may also be an aid in injury prevention or rehabilitation.

Muscular strength in the studies reviewed was of either static or dynamic nature. The majority of the studies regarding static and dynamic strength stated there was a relationship between static muscular strength, dynamic strength and motor ability.

Delimitations

The following are delimitations to this study:

1. seventeen members of the 1972 University of North Dakota football team,

2. four static strength tests of knee extension, shoulder flexion, shoulder extension, and forearm extension,

3. to measure only strength of the arms and legs,

4. to record static strength only,

5. those tested were randomly selected from the spring squad of the 1972 team at the University of North Dakota.

Limitations

This study was limited by the lack of control of each subject's motivation and lack of control over each subject's diet, sleep habits and other extraneous activities.

CHAPTER II

METHODOLOGY

The testing consisted of four measurements of static strength: shoulder extension, shoulder flexion, elbow extension, and knee extension. The test of extension of the arm at the shoulder recorded the strength exerted by the prime movers, the posterior deltoid, pectoralis major, latissimus dorsi and teres major. Flexion of the arm at the shoulder measured the main movers in flexion. Most prominent were the coracobrachialis, anterior deltoid and clavicular portion of pectoralis major. The knee extension test was designed to measure effort produced by the quadriceps, vastus medialis, vastus lateralis, vastus intermedius, and the rectus femoris. The tricep brachii was the prime mover evaluated for muscular strength in the testing of elbow extension.

Description of Apparatus Used in Testing

All testing was done with subjects sitting in the strength chair, located in the exercise physiology laboratory at the University of North Dakota. Figure 1 shows the strength chair. Two cables and slings used in testing were available in the physiology laboratory.

Test results were recorded by use of a cable tensiometer, which was available in the physiology laboratory. The use of a tensiometer was originally developed for determining muscle strength by

Clarke (1). The tensiometer in the physiology laboratory was manufactured by the Pacific Scientific Company.

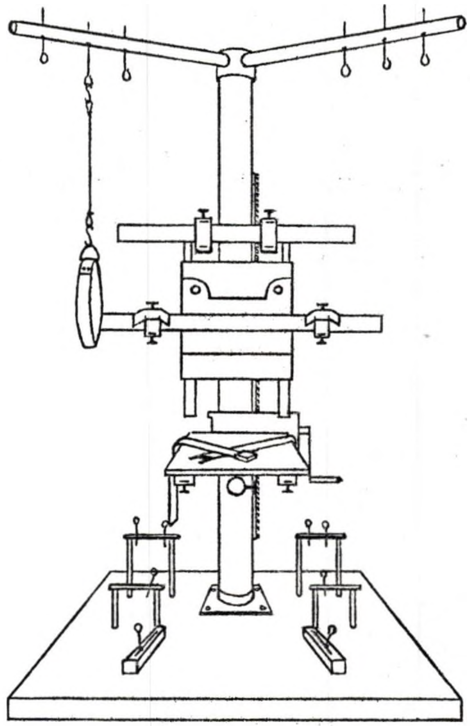

Fig. 1.--Strength Chair at the University of North Dakota

Characteristics of the Test

The objectivity of the test was controlled by the testing procedure described by the investigator and his administration of the test. Objectivity was further aided by use of the cable tensiometer and its objective measurements.

The validity of the test items was accepted at face validity because of minimum complexity of test items. The muscle groups tested were defined and their use in football acknowledged.

A pilot study in 1971 using University of North Dakota freshman football players was used to determine the reliability of test items. The Spearman Rank-Order Coefficient method of correlation was used in the statistical analysis, to determine the reliability of test items. The data used were ordinal data with the highest score ranked number one. Scores from both the test and retest were ranked. A rank difference correlation between the tests resulted in the following values:

TABLE 1

TEST-RETEST RELIABILITY COEFFICIENTS

Test Item	rho
Knee Extension	+1.00
Shoulder Flexion	+0.89
Shoulder Extension	+0.86
Elbow Extension	+0.89

Subjects

A sample of twenty-one subjects was selected from an advanced conditioning program for University of North Dakota football players. Four of the original sample were unavailable at the final testing date, which provided for a final sample of seventeen subjects. The participants were selected from both the offensive and defensive squads. All participants were subjected to a similar practice program during the spring practice period, which included a daily isometric program. The practice schedule is found in Appendix A, page 26.

Test Procedures and Dates

Spring football started at the University of North Dakota on April 10, 1972; the initial tests were administered on April 6 and

April 7. All four test items were administered to each individual in a consecutive manner. A scrimmage on May 6, 1972, concluded spring football. Final testing procedures were administered on May 8 and May 9 in the same manner as the pre-test administration.

Test Item Description

The testing consisted of four areas of the body which play an important part in football participation. The four tests involved: (1) shoulder extension, (2) elbow extension, (3) shoulder flexion, and (4) knee extension.

A. Shoulder Extension:

1. Starting position - The angle set between the humerus and the body line was at 90 degrees with the angle at the elbow also at 90 degrees.
2. Procedure - The sling was placed over the arm and put in position midway between acromion process and the lateral epicondyle of the humerus. The sling and cable were then attached to arm of chair extending above and over subject's shoulder. The tensiometer was then placed at midpoint of the cable, facing the tester. The subject was instructed to force down against sling with maximum effort. Tensiometer was read to nearest whole unit. Figure 2 shows position of the subject performing the shoulder extension test.

B. Elbow Extension:

1. Starting position - The subject's elbow was placed in the elbow stabilizer and adjusted so that the humerus fell along the body line. The angle at the elbow

joint was set at a right angle. The sling was placed over the forearm midway between olecranon process and the ulnar styloid process. The sling and cable were attached to V of strength chair arm so that when the subject exerted force downward the angle remained at 90 degrees. In all four tests the tensiometer was read in the same manner. Figure 3 shows position of the subject performing the elbow extension test.

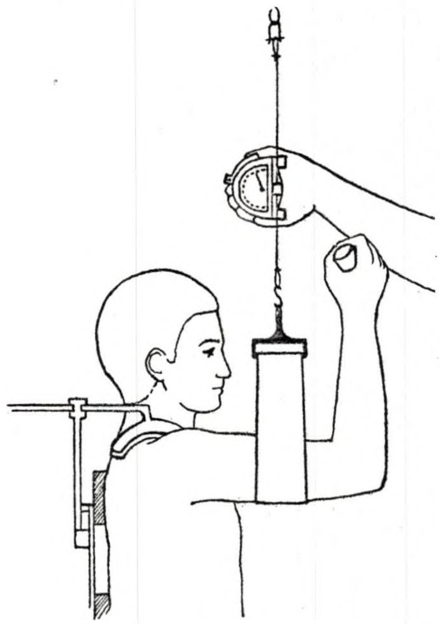

Fig. 2.--Position of Subject in Shoulder Extension Test

C. Shoulder Flexion:

1. Starting position - The angle between the humerus and the body line was set at 90 degrees with the angle of the elbow at 90 degrees also. The palm was turned toward the subject.

2. Procedure - The sling was placed over the arm and positioned midway between the acromion process and

the lateral epicondyle of the humerus. The sling and cable were attached to base of strength chair so that when subject exerted force the angle at the joint remained at 90 degrees. At the direction to exert force the subject exerted force by shoulder flexion with angle remaining at 90 degrees. Figure 4 shows position of the subject performing the shoulder flexion test.

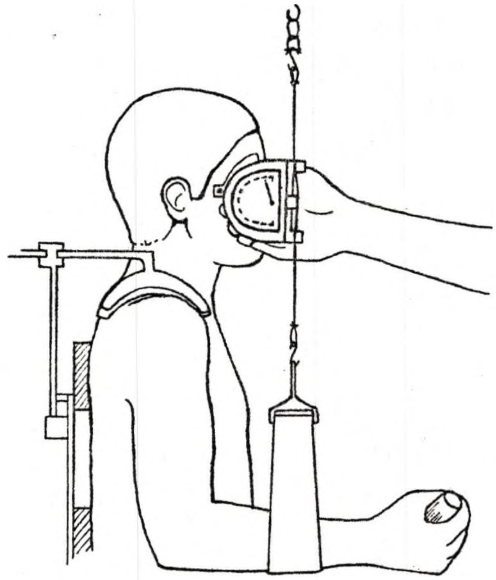

Fig. 3.--Position of Subject in Elbow Extension Test

D. Knee Extension:

1. Starting position - The knee stabilizer was adjusted so that it fit under and behind the knee joint comfortably. The angle of knee joint was 90 degrees. The subject was instructed to grasp the chair seat with both hands.

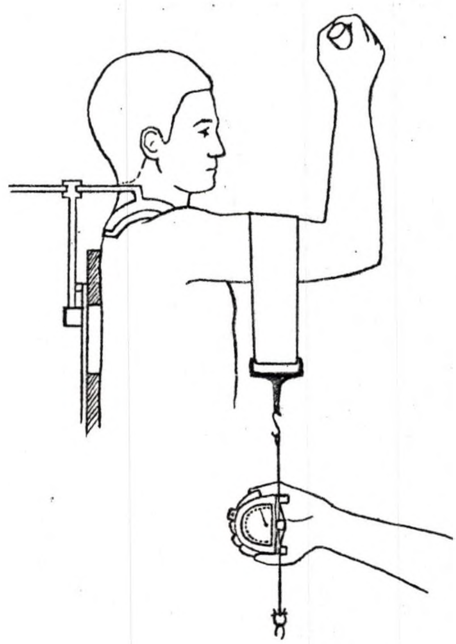

Fig. 4.--Position of Subject in Shoulder Flexion Test

2. Procedure - The sling was placed over the calf and positioned midway between the lateral malleolus (of the ankle) and the head of the fibula. The cable and sling were then attached to chain attached at the back of the chair base. The tensiometer was placed on the cable and the subject instructed to exert maximum force ahead against the sling. Figure 5 shows position of the subject performing the knee extension test.

In all tests, measurements were taken from the right side of the body. Each subject was administered three separate tests of each item with the average of the three being used as the final result. In tests measuring arm and shoulder strength the subject grasped the chair seat with his left hand. In all test items the administrator observed the subjects for twisting in chair or other incorrect procedure. If the subject incorrectly followed test instructions, the test was readministered after a brief rest period. All test results were recorded in tensiometer units. The needle was closely observed by the tester to detect any jerking by the subject which would result in an inaccurate score. In the testing procedure the subjects were not allowed to be aware of tensiometer readings until testing was completed.

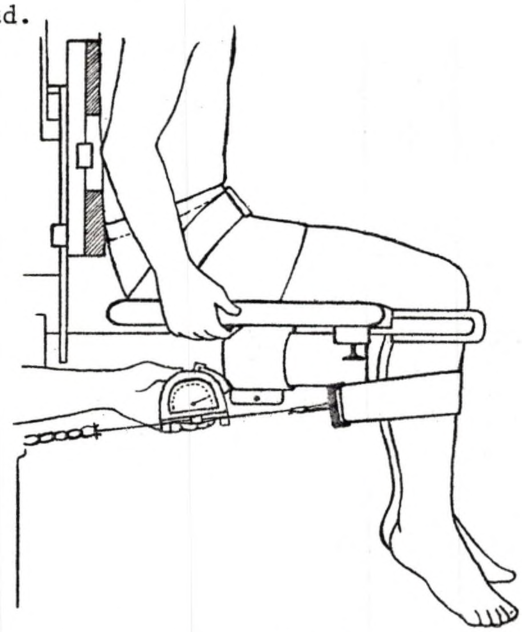

Fig. 5.--Position of Subject in Knee Extension Test

CHAPTER III

TREATMENT AND ANALYSIS OF THE DATA

Statistical Procedure

It was the purpose of this investigator to determine whether or not there was significant change in muscular strength on the part of football players at the University of North Dakota during the Spring season. This was determined by pre-season and post-season testing of muscle groups used in the playing of football.

The sample in this situation was measured against itself on the same criterion. A t test applicable for the testing for significant differences among related groups was selected for use in this study. The t tests for significance were conducted at the .05 level.

The following test items of static strength were checked for significant differences: shoulder extension, shoulder flexion, elbow extension and knee extension.

Complete data for all tests and the mathematical treatment used in the statistical analysis of test items are presented in Appendix B, page 29.

Null Hypothesis

There were no significant differences among the pre-season and post-season test items of static strength.

Analysis of Results

Shoulder extension

The pre-test showed a total of 762 units and the post-test resulted in a total of 739. The difference between the two sums was 23, this showing a slight decrease. The t value was .766 with 16 degrees of freedom ($p > .05$). With 16 degrees of freedom a t value of 2.120 at the .05 level was needed to show a significant change in all the test items.

Shoulder flexion

On the test of strength of shoulder flexion the pre-test sample produced a total of 503 tensiometer units. The post-season test produced a sum of 451 units resulting in a difference of 52 units between the pre- and post-test results. This difference showed a decrease in the total of the post-season test. The t value was 2.826 with 16 degrees of freedom ($p < .05$).

Elbow extension

The sample in the pre-season test of elbow extension produced a total of 368 tensiometer units. In the post-season test the total resulted in a sum of 432. The difference in the two totals of the pre-test and post test was 64. This particular difference represented an increase in the post-season test over that of the pre-season test. The t value was 2.885 with 16 degrees of freedom ($p < .05$).

Knee extension

The pre-season test scores of knee extension totalled 1364 tensiometer units. In the post-season test the total was 1202. These results showed a difference of 162 units. This represented a decrease from the pre-season test to the post-season test. The t value was 3.750 with 16 degrees of freedom ($p < .05$).

TABLE 2

SUMMARY TABLE OF THE SIGNIFICANCE OF THE DIFFERENCES BETWEEN THE PRE-TESTS AND POST-TESTS

Area of Comparison	Pre-Test	Post-Test	Difference	t value
Shoulder Extension	762	739	- 23	.766
Shoulder Flexion	503	451	- 52	2.826*
Elbow Extension	368	432	64	2.885*
Knee Extension	1364	1202	-162	3.750*

*Significant at .05 level.

The data illustrated in Table 2 show that there were significant changes in all test results with the exception of the shoulder extension test. In the shoulder extension test there was a slight decrease, but this difference was not significant at the .05 level. Shoulder flexion and knee extension tests indicated results which showed a significant decrease. The summary table results showed a significant change between the pre-test and post-test of elbow extension. In this test the difference showed an increase in the post-test results.

CHAPTER IV

DISCUSSION

Football is a sport in which strength is generally thought to be a major requisite. Muscular strength is necessary in the execution of various football techniques and fundamentals. It is probable that muscular strength affects the success and performance of the football player in this competitive game. This investigator, as a football coach, wanted to determine if there were muscular strength changes during a football training program. The football training program that was investigated was one with which the investigator was familiar and favored as a training routine.

Several methods of recording muscular strength were considered for use in this investigation. These included use of a leg dynamometer, pull ups, a universal weight machine, and a cable tensiometer. A review of literature supported the use of a cable tensiometer. Clarke (1), after having observed several testing instruments, stated that the tensiometer was the most stable and generally useful of the testing instruments. Clarke added that the tensiometer had the greatest precision and was free of faults found in other devices.

Muscular strength changes did occur in the sample between the pre-season and post-season tests. The only significant gain shown was in the test of elbow extension. The gains in this test may have been a result of a four minute isometric period in which all team members took part every practice session. The isometric period was designed to contribute to the development of the arms, legs, neck, and shoulder areas. In the isometric training there was an exercise which had a likeness to the elbow extension test. This, with the fact that an advanced conditioning class for football players during the winter included no specific exercise for elbow extension, may have been the reason for the gain of strength shown.

Shoulder extension, shoulder flexion and knee extension muscular changes showed a decrease in muscular strength. These losses were significant in shoulder flexion and knee extension, and non-significant in shoulder extension. These losses seemed to indicate that practice sessions at the University of North Dakota did not contain exercises that developed strength in shoulder extension, shoulder flexion or knee extension.

The decreases in strength may have been the result of the advanced conditioning program in which all football members took part. This program took place the three months prior to the spring practice season. The advanced conditioning program included a strenuous strength developing program for all involved. It is likely that, following such a strength developing program, there would be a decrease in muscular strength after the participants had completed 20 practice sessions that did not contain a vigorous strength developing program.

The losses indicated in shoulder extension, shoulder flexion and knee extension might have been due to the fact that the spring practice season contained a daily schedule which involved a large amount of contact work. It is suggested that this could have caused a decrease in strength.

Certain uncontrollable factors may have influenced the results of the test items. It was not possible to control the amount of rest or the health and physical condition of the subjects. There was no way in which outside activities which may have weakened the subjects could be controlled. The motivation or lack of it could not be controlled by the investigator.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Four tests of static muscular strength were administered to seventeen members of the University of North Dakota football team. The tests were administered before and after the spring practice season. The tests measured muscular strength of body areas believed important for football participation. The test items included shoulder extension, shoulder flexion, elbow extension and knee extension.

Conclusions

As a result of the findings, this study supports the following conclusions:

1. Muscular strength, as measured by the knee extension test and shoulder flexion test, decreased significantly.

2. Muscular strength, as measured by the shoulder extension test, decreased but not significantly at the .05 level.

3. The elbow extension test results exhibited an increase in the measurement of muscular strength.

4. The twenty day spring practice season at the University of North Dakota resulted in muscular strength changes among the subjects tested.

Recommendations

As a result of this study the following recommendations were made:

1. An investigation should be made to determine the effect of strength decreases on football performance.

2. It is recommended that a similar study be done to measure strength retention over a normal interscholastic fall season.

3. It is recommended that a similar study be conducted using dynamic strength measurements.

4. Further study should be made to determine the effect a controlled weight program may have on strength development and retention during a season.

5. Finally, it is recommended that a similar investigation be done to determine strength development and retention at different points in both an off-season conditioning program and a football season.

APPENDIX A

APPENDIX A

FOOTBALL PRACTICE SCHEDULE AT THE UNIVERSITY OF NORTH DAKOTA

A specialty period of thirty minutes in length began the daily practice routine. During this period the entire squad was separated into specific units. This period allowed time for individual development in areas such as passing, kicking, defensive and offensive techniques. This portion of practice was followed by a four minute period of calisthenics.

The four minute calisthenics period consisted of toe-touchers, side-straddle hops, trunk twisters and isometrics. The isometric routine was designed for the neck, shoulder and leg areas of the body. Athletes were paired for the isometric exercises, with one providing the resistance for the other.

Agility drills followed the calisthenics period. These drills included form running, high knee running, three man roll, foot fires, and wave drills. The agility period lasted five minutes.

The circuit training period consisted of four basic football fundamentals. These were blocking, tackling, running, and flexibility. The squad was separated into four groups; each group spent two minutes at each of the fundamental stations.

A unit period followed the circuit training period. In the unit period the team was divided into specific groups--defensive line, defensive secondary, offensive line, and offensive backfield. This period stressed technique, and unit strategy. This portion of practice lasted approximately thirty minutes.

The team period brought the defensive and offensive units together. Coordination of specific unit work was desired in this period. Included in this team period was ten minutes devoted to the kicking game. Practice concluded with the running of sprints, which ranged from ten to fifty yards.

APPENDIX B

APPENDIX B

RAW DATA OF SHOULDER EXTENSION TEST

Subject	Pre-Test	Post-Test	D	D^2
1	48	48	. .	. .
2	46	44	2	4
3	44	59	- 15	225
4	37	37	. .	. .
5	47	52	- 5	25
6	41	36	5	25
7	42	35	7	49
8	44	39	5	25
9	35	36	- 1	1
10	49	48	1	1
11	64	55	9	81
12	41	42	- 1	1
13	53	58	- 5	25
14	14	17	- 3	9
15	57	43	14	196
16	47	51	- 4	16
17	53	39	14	196
	762	739	ΣD 23	ΣD^2 879

THE ANALYSIS OF THE SHOULDER EXTENSION TEST

t Test of Significance Between Related Groups

$N = 17$

$\Sigma D = 23$

$\Sigma D^2 = 879$

$df = 16$

$$t = \frac{\Sigma D}{\sqrt{\frac{N\Sigma D^2 - (\Sigma D)^2}{N - 1}}}$$

$$t = \frac{23}{\sqrt{\frac{17 \cdot 879 - (23)^2}{17 - 1}}}$$

$$t = \frac{23}{\sqrt{\frac{14943 - 529}{16}}}$$

$$t = \frac{23}{\sqrt{\frac{14414}{16}}}$$

$$t = \frac{23}{\sqrt{900.875}}$$

$$t = \frac{23}{30.014}$$

$$t = .766$$

Not significant at the .05 level

RAW DATA OF SHOULDER FLEXION TEST

Subject	Pre-Test	Post-Test	D	D^2
1	38	42	- 4	16
2	28	17	11	121
3	33	31	2	4
4	14	17	- 3	9
5	24	32	- 8	64
6	35	26	9	81
7	33	34	- 1	1
8	20	15	5	25
9	31	23	8	64
10	35	28	7	49
11	29	36	- 7	49
12	23	22	1	1
13	37	27	10	100
14	13	17	- 4	16
15	47	26	21	441
16	38	33	5	25
17	25	25	. .	. .
	503	451	ΣD 52	ΣD^2 1,066

THE ANALYSIS OF THE SHOULDER FLEXION TEST

t Test of Significance Between Related Groups

$N = 17$

$\Sigma D = 52$

$\Sigma D^2 = 1,066$

$df = 16$

$$t = \frac{\Sigma D}{\sqrt{\frac{N \Sigma D^2 - (\Sigma D)^2}{N - 1}}}$$

$$t = \frac{52}{\sqrt{\frac{17 \bullet 1,066 - (52)^2}{17 - 1}}}$$

$$t = \frac{52}{\sqrt{\frac{18122 - 2704}{16}}}$$

$$t = \frac{52}{\sqrt{\frac{15317}{16}}}$$

$$t = \frac{52}{\sqrt{338.622}}$$

$$t = \frac{52}{18.40}$$

$$t = 2.826$$

Significant at the .05 level

RAW DATA OF ELBOW EXTENSION TEST

Subject	Pre-Test	Post-Test	D	D^2
1	18	20	- 2	4
2	14	16	- 2	4
3	26	32	- 6	36
4	16	17	- 1	1
5	23	32	- 9	81
6	23	30	- 7	49
7	26	21	5	25
8	17	29	- 12	144
9	14	25	- 11	121
10	17	20	- 3	9
11	23	31	- 8	64
12	21	21	. .	. .
13	28	39	- 11	121
14	12	8	4	16
15	32	34	- 2	4
16	23	26	- 3	9
17	35	31	4	16
	368	432	ΣD-64	$\Sigma D^2$704

THE ANALYSIS OF THE KNEE EXTENSION TEST

t Test of Significance Between Related Groups

$N = 17$

$\Sigma D = 162$

$\Sigma D^2 = 3,300$

$df = 16$

$$t = \frac{\Sigma D}{\sqrt{\frac{N\Sigma D^2 - (\Sigma D)^2}{N - 1}}}$$

$$t = \frac{162}{\sqrt{\frac{17 \cdot 3300 - (162)^2}{17 - 1}}}$$

$$t = \frac{162}{\sqrt{\frac{56100 - 26244}{16}}}$$

$$t = \frac{162}{\sqrt{\frac{29856}{16}}}$$

$$t = \frac{162}{\sqrt{1866}}$$

$$t = \frac{162}{43.197}$$

$$t = 3.750$$

Significant at the .05 level

RAW DATA OF KNEE EXTENSION

Subject	Pre-Test	Post-Test	D	D^2
1	95	88	7	49
2	99	99	. .	. .
3	66	58	8	64
4	38	46	- 8	64
5	88	61	27	729
6	98	90	8	64
7	64	61	3	9
8	74	73	1	1
9	86	75	11	121
10	85	68	17	289
11	93	76	17	289
12	69	56	13	169
13	99	92	7	49
14	70	66	4	16
15	93	60	33	1089
16	54	57	- 3	9
17	93	76	17	289
	1364	1202	ΣD 162	ΣD^2 3,300

THE ANALYSIS OF THE ELBOW EXTENSION TEST

t Test of Significance Between Related Groups

$N = 17$

$\Sigma D = -64$

$\Sigma D^2 = 704$

$df = 16$

$$t = \frac{\Sigma D}{\sqrt{\frac{N \Sigma D^2 - (\Sigma D)^2}{N - 1}}}$$

$$t = \frac{-64}{\sqrt{\frac{17 \cdot 704 - (-64)^2}{17 - 1}}}$$

$$t = \frac{-64}{\sqrt{\frac{11968 - 4096}{16}}}$$

$$t = \frac{-64}{\sqrt{\frac{7872}{16}}}$$

$$t = \frac{-64}{\sqrt{492}}$$

$$t = \frac{-64}{22.181}$$

$$t = -2.885$$

Significant at the .05 level

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